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nary usage of the term. But in what usage of the term it is science he does not reveal.

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REVIEWS AND ABSTRACTS OF LITERATURE

La théorie physique; son objet et sa structure. P. DUHEM. Paris: Chevalier & Rivière. 1906. Pp. 450.

This volume is the book-form of the series of articles which first appeared in the *Revue de philosophie* for 1905.

The author is recognized as one of the foremost authorities and scholars in his line; from him there have come a number of highly valued and exhaustive treatises on chemical mechanics, on hydrodynamics and on electricity and magnetism, as well as other and more simple works written with a distinctly didactic purpose. One of the most important characteristics of all of this systematic work in these diverse fields is the acceptance and use, in each of them, of certain fundamental principles by which a unification or 'natural classification' is brought into the treatment of the various classes of physical phenomena. That principle which in particular enables him to do this is the generalized 'second law,' which was developed first in thermodynamics, and according to which, in its extended form, every energy-transfer 'goes out' from the higher potential to the lower, provided such a potential difference is uncompensated, etc. The author thus allies himself closely with Nernst, Gibbs, Mach and a number of other leading physicists. From time to time he has appeared as an opponent of Poincaré concerning various questions.

This present work of his, together with some other contributions, places him in that rapidly growing group of scientists who look at their science retrospectively, analytically, broadly, or, as one might say, philosophically. In reading it one feels that he has before him the exposition of a master, of one who not only knows and uses the technique, but who also sees the logically and historically significant thing, and who speaks, therefore, with well-justified confidence. However, in this review it is possible only to indicate a few important main points out of much that is of great value in the matter presented.

The volume consists of two parts, the first dealing with 'the object of physical theory,' the second with its 'structure.' The first part is divided into four chapters, and each of these into a number of sections.

In Chapter I., in which there is discussed the relation between 'physical theory and metaphysical explanation,' M. Duhem finds that neither historically nor logically is the former subordinate to the latter, but that it is autonomous. To state simply just what the author means by 'physical theory' is at this point impossible, since, indeed, the elucidation of this is the purpose, in great part, of his subsequent discussions. By 'metaphysical explanation' there are referred to, as it becomes clear later, views as to the ultimate nature of physical phenomena, assumptions as to something behind sense-given data and hidden from immediate perception. Metaphysics, he finds, has been sterile as a source from which to draw principles for physical theory; but he does not refer here to such *a priori* and constitutive principles as those of Kant's critique.

Chapter II. The purpose of physical theory is, indeed, not explanation; rather, physical theory is a system of mathematical propositions deduced from a small number of hypotheses, and its purpose is to represent 'as simply, completely and exactly as possible an ensemble of experimental laws.' Between theory and experimental laws a fairly exact distinction is made, here and subsequently. Four 'operations' are necessary to theory: first, the choosing of simple properties and the establishing, by measurement, of a correspondence between these and mathematical symbols; measurement gives for each physical property a numerical value of its sign. Secondly, hypotheses must be chosen as principles of deduction, by which the various kinds of quantities are brought into relation. Thirdly, there is the mathematical development, in which the various hypotheses of a theory are combined according to the rules of mathematical analysis. Fourthly, the consequences thus drawn can be translated into judgments concerning physical properties; if it be found that these judgments, when compared with experimental laws, agree approximately, then has theory fulfilled its purpose.

Chapter III. Such a theory—and here is an important point methodologically—constitutes a *natural classification* of experimental laws; thereby do their real affinities, their ontological relations, become known, not, however, in a manner which consists in or is satisfied by the formation of images and the construction of models. The purpose of theory is, then, to condense, to classify, to predict. But do not these constitute explanation? No! 'Something behind the senses' is not thereby gotten at, but rather, by an analysis and comparison made by mathematical means, there are discovered common properties which can be treated and known only by symbolic methods. This is called by our author representation or description, and constitutes the autonomy of physical science.

Chapter IV. Not all men, however, can 'comprehend' such an abstract theory; some must present things as seen or touched, and, therefore, they construct models for the details of theory. This characterizes the English physicist in particular, with his predilection for mechanics and explanation. On the other hand, for the French and Germans a physical theory is a logical system rigorously deduced and satisfying reason rather than imagination; if algebra is used, it can be replaced by logic. Starting with, for example, two categories of distinct phenomena, within the realm of theory it may be found that the fundamental algebraical equation of one is identical with that of the other; each, therefore, helps to 'clear up' the other.

The second part consists of seven chapters.

Chapter I. It may be difficult to get such a mathematical physics, logically rigorous, etc., but it can be accomplished by the use of symbolic methods. Each idea can be represented by a sign, and so defined unambiguously; each phase of reasoning can be replaced by an operation which combines signs according to fixed rules. For this it is necessary that each notion should have a numerical value, each physical attribute be signified by a numerical symbol. Here the well-known distinction is made, that physical phenomena are both extensities and intensities. To the former the associative and commutative laws are applicable; the symbolic addition $A + B + C + \cdots$ can be replaced, through the medium of measurement of length, surface, volume, etc., by real arithmetical addition. On the other hand, intensities can not be 'summed' or analyzed in this way. 'Each intensity of a quality has its own individual character'; it does not contain as an integral part the lesser intensity. However, contrary to the view of some physicists that their science deals only with extensities and that these are the realities behind the qualities as appearances, this does not make it impossible to express the various intensities of a quality by numbers. For physical theory represents sense qualities by signs or symbols; these are algebraical; they are made numerical by measurement. The means for this is a *scale,* which is the quantitative effect of a qualitative cause. Thus the intensity of a quality can be represented adequately by a numerical symbol. Then an algebraical treatment is possible; the scale mediates the substitution of numbers, which can be added, although they refer to intensities which can not be. In this way physical science can be built up without any dependence on hypotheses 'as to the nature' of phenomena; such a physics is descriptive, 'representative,' autonomous.

Chapter II. But, proceeding in this manner, a minimum number of simple irreducible qualities should be made use of. What is the criterion for these? Duhem's answer to this is important philosophically. Instead of drawing the criterion from philosophy, as does explicative physics, one should let this result from autonomous procedure. It is not known beforehand what qualities are primary; this is a relative term, meaning 'not yet reduced.' In illustration there is cited the reduction of light to an electromagnetic phenomenon. The geometrical symbol for light is a curved line; treating this mathematically, its components, etc., make it possible to write certain equations to partial derivatives so that the empirical laws of propagation, reflection, refraction and diffraction are 'classified' with an admirable brevity and order. Proceeding in an analogous way for dielectrical polarization, it is finally found that the equations for this have the same form, the coefficients the same numerical value, as do those for 'luminous vibrations.' The conclusion is that 'light is not a primary quality,' that 'light vibration' is nothing else than a dielectric polarization periodically variable.

Chapter III. treats of 'mathematical deduction'; the rôle of this is the development of that 'edifice' whose foundation is the measurement of qualities and the choice of hypotheses. It forms an intermediate operation with the concrete at either end, and proves useful or not, according as the conditions started with enable prevision.

Chapter IV. presents a standpoint which would be of great value to those extreme empiricists who would have all physical science consist only in 'getting at the facts experimentally' and would exclude all theory. Our author shows that the 'experience' of the physicist is not simply observation, but is also its theoretical interpretation. Instruments must be used, and these can be constructed and the results which they give can have a meaning only in the light of theory. Words like volts, electro-magnetic force, etc., do not express directly an object visible and tangible; the scientist's language presupposes theory. Instruments can be used only if it is possible to substitute for concrete objects a representation, abstract, symbolic, schematic, and to submit this combination of 'abstract' representations to a deduction and calculation which imply adhesion to theories. Only in this way does the interpretation, *i. e.,* the meaning, of an experiment become possible. By the use of the concrete instrument before him the physicist gets definite numerical values for certain symbols created by theories; but over against this there is 'in his mind' the 'ideal' instrument, and it is upon this that he reasons.

Chapter V. deals with the character of a physical law. "Laws are symbolic relations." They transcend themselves, for between symbol and thing a correspondence is established by means of instruments, thus implying theory. "Strictly speaking, a law is neither true nor false, but approximate." For each series of facts there may be an infinity of laws, and conversely. Because it is both approximate and symbolic, every physical law is provisory and relative; by progress it gains in precision, and since the symbols may prove too simple to represent reality completely and adequately, it demands continual retouching.

Chapter VI. Under what circumstances is physical theory confirmed? For this confirmation a twofold apparatus, concrete and ideal (schematic), is necessary. But, since both the concrete instrument and the interpretation of the results gained by it, etc., imply adhesion to an 'ensemble' of laws, in the event of failure to confirm, not one law but the ensemble is shown to be at fault or to require modification and retouching. For this reason the 'crucial experiment,' which would proceed by eliminating all hypotheses but one and testing this one, is impossible; this elimination can not be practised. The only experimental control which is not illogical consists in comparing the entire system of physical theory with the ensemble of experimental laws and *appraising* if the former represents the latter in a satisfactory manner.

In the development of physical theory, that which the author has called the third step, use must be made not only of symbols and of logical laws and algebraic rules, but also of postulates. The selection of these is, to a certain extent, arbitrary; there must be no contradiction among them; but neither they nor the intermediate steps of the development which is made by their use need seek the direct control of sense experience. The 'operations' of the development have no 'physical sense.'

Chapter VII. What, then, determines the choice of hypotheses? The condition is not that they should have a 'physical sense,' nor that they should give the 'nature of things.' And they are not purely inductive laws, for pure induction is impossible. Rather, hypotheses should be so chosen that by their use in their ensemble mathematical deduction can draw consequences which represent with sufficient approximation the ensemble of experimental laws. The schematic representation, by mathematical symbols, of experimental laws is the purpose of physical theory. The hypotheses chosen and used are accordingly the result of a progressive evolution, and a repeated retouching is necessary. It may even be said that they are not chosen, but that they 'germinate' in the physicist because of his habits of thought in the traditions of the science.

The author closes the volume with a discussion as to the manner in which physics should be taught; he finds that in every exposition a compromise must be made between the exigencies of logic and the intellectual needs of the student.

In this review it has been impossible, because of the full and thoroughgoing presentation which the author makes, to do more than give an outline of his position with reference to the many phases of physical science. However, the volume contains a great deal which is both stimulating to reflection and demanding of discussion. Evidence of this is to be found, indeed, in the very lively discussions and appreciative reviews which it has excited in the French periodicals. The general position which M. Duhem takes seems to me to be of especial opportuneness and interest in connection with current agitation as to radical empiricism and pragmatism. To his view as to hypotheses, the 'standing' of qualities, the purpose of theory, and the means to attain this, the pragmatist might, perhaps, point with satisfaction at finding a position, sympathetic to his own, yet taken by an active physicist. But for M. Duhem this is methodological pragmatism. With the position which goes farther than this and finds in this pragmatism the implications of an ontological doctrine, one with whose outlines we have all been made familiar recently, doubtless much to their disappointment some of our pragmatists would not find him to be in agreement. Capable, indeed, of reasoning rigorously in the field of mathematical physics, he fails to disclose the discovery of any such implications. Is this omission, or does rigorous thinking desert him here?

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The Psychology of the Simple Arithmetical Processes: A Study of Certain Habits of Attention and Association. CHARLES E. BROWNE. *The American Journal of Psychology,* January, 1906. Pp. 1–37.

The study is provided with a full table of contents. The writer's careful summaries will be of use to readers, who will find the article worth their attention. Nine subjects served in the experiments, which were concerned with two types of procedure in arithmetical process: (1) purely mental from visual cues, (2) written and more complex.

It is found that a specific mental attitude corresponds to each of the four main processes, and this is further differentiated as multipliers or